Physiological adaptations to aerobic exercise

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Introduction

Physical exercise is any physical activity that improves and maintains fitness, health and well-being of people. Endurance training produces changes in our body: physiological adaptations. Then, we can define physiological adaptations to physical exercise as the changes that occur in the body in response to the presence of a particular stimulus, in this case exercise.

The main objective of this work is to observe what kind of adaptations occurs in four of the major systems involved in the realization of physical activity: the muscular, cardiovascular, respiratory and neuroendocrine systems. Changes affecting these systems modify the body health of a trained subject.

Exists an important difference between the terms "adaptation" and "response" to exercise. "Response" are the changes that makes our body during exercise. After exercise, your body returns to a basal state. Adaptation change's occurs after a relatively large period of training and lasts more time. These changes modify your body response during exercise.

Methods

Literature search in databases such as Medline or Pubmed, using the advanced search tool to obtain the right results . The search was restricted to papers published in the last 15 years but it used the 80s and 90s too, due to the great advances in sport that occurred in those years. It also includes information from basic physiology textbooks to explain the most purely physiological sections.

Featured references

Chicharro, J.L. **Fisiología del ejercicio**. 3º ed. Editorial Médica Panamericana, Buenos Aires, 2010

Fagard, R**. Athletes heart** General cardiology. Heart 2003; 89 :1455–1461

Mador, M.J., **Respiratory muscle fatigue and breathing pattern**. Chest, 1991;100:1430-1435

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CARDIOVASCULAR ADAPTATIONS

- **Sinus bradycardia** due to changes in SNA regulation:
  - Decreased heart frequency (FC<60) bpm
  - Visible on ECG study, with another changes (FIG.1):
    - Irregular QRS waves
    - Increased voltage QRS waves
    - Early repolarization
    - T waves are high with a peak shape in V1, V2 and V3
- Increased heart volume and wall thickness.
  - Increased left heart:
    - Atrium (but without exceeding normal limits)
    - Ventricle: 20% larger than sedentary heart.
  - Increased right heart: proportional growth to the left heart.
- Increased heartbeat volume at rest, due to increased end-diastolic volume.
- The increased capillary density at heart is proportional to thickening of the heart wall.
- Decreased energy consumption of myocardial cells . Glucose prioritized as the main fuel.
- Increased capillary in muscle and lung: angiogenesis

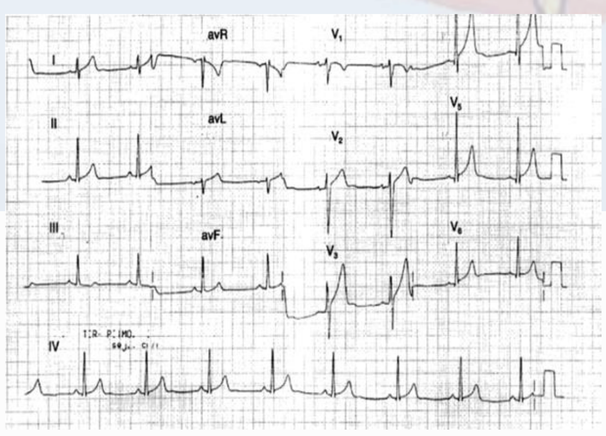

FIG.1 Endurance athlete ECG's

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MUSCULAR ADAPTATIONS

In endurance athletes ,the type I fiber concentration (around 60%) is higher than sedentary people, but this fiber concentration was genetically defined. Despite this, the muscle fibers (independently if are type I or II) can do the followings changes:

- Increased number of capillary per fiber→ gas exchange optimization.
- Increased mitochondrial number→ increased oxidative activity.
- Increased triglyceride and glycogen intracellular stores
- Increased lipoprotein lipasa activity→ muscle prioritizes lipids as a fuel→ saving glycogen.

NEUROENDOCRINE ADAPTATIONS

- Sympatho-adrenal axis:
  - Decreased sensitivity of catecholamine (norepinephrine and epinephrine) receptors→ the catecholamine increase are attenuated during exercise
- Erythropoietin: adaptations not found
- Pancreatic hormones:
  - Insulin: similar pattern to the catecholamine→ decreased insulin receptors sensitivity (FIG.2).
  - Glucagon: the same pattern as observed in insulin (FIG.3).
- Hypothalamus-pituitary axis:
  - GH: no differences between sedentary and trained subjects
  - ACTH: inconclusive studies→ was observed both decreased and increased sensitivity of ACTH receptors.
- Sex hormones:
  - Male
    - Testosterone: inconclusive studies→ Some authors observe decreased testosterone levels in plasma, but others don't appreciate variations
  - Female
    - LH and FSH: low energy availability, low leptin level and high stress hormone concentration interrupts de hypothalamus-pituitary-ovarian axis→ Decreased FSH and LH levels

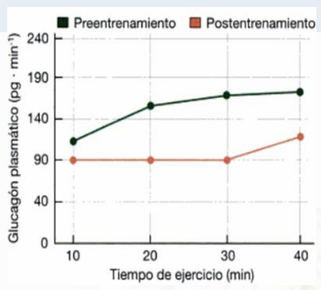

FIG. 2 and 3: Response of plasma insulin concentration (right) and glucagon (left) during exercise , before and after 20 weeks of endurance training.

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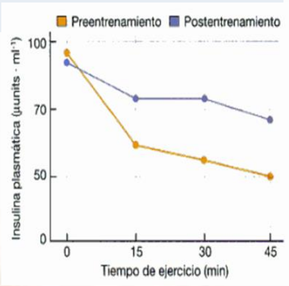

RESPIRATORY ADAPTATIONS

The adaptations in the respiratory system are observed in the response to physical exercise. These adaptations depend on the exercise intensity:

- Max. intensity: trained subjects resist better the increase of [CO2] in blood and the decrease of [O2] due:
  - He has increased VE max
  - He has decreased CO2 sensitivity
- Moderate intensity:
  - Decreased energy used by pulmonary ventilation. This, increases the [O2]available to be used by exercising muscles.

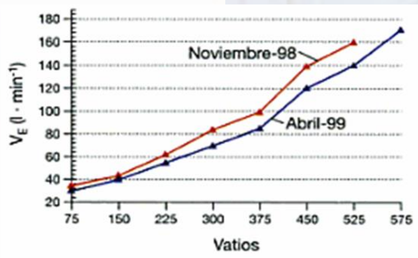

FIG.4 Response of pulmonary ventilation (VE) before (red line) and after (blue line) training period of 5 months

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Conclusions

Aerobic exercise produces significant adaptations in the four systems discussed .

1- In the cardiovascular system, have been observed sinus bradycardia, increased heart size and a resting heartbeat blood volume. Moreover, the size and flow of the vessels that leads to the heart increase too. In addition, the glucose metabolism is optimized. Peripherally, angiogenesis occurs in the muscular system and the lungs.

2- Muscular adaptation is performed by increased vessels per muscle fiber. In addition , the muscle cells increase their mitochondria's number and glycogen and triglycerides stores. The muscles prefer lipids than glucose as a fuel.

3- In the respiratory system, we observe that trained subjects respond better to high concentrations of CO2 in blood than sedentary (at max. intensity). On the other hand, decrease the energy demand of pulmonary ventilation increase the available O2 that it could be used by other muscles.

4- Finally, it is difficult to obtain a clear conclusion about neuroendocrine adaptations to exercise, due to the significant discrepancies found from sources. However, we can see a decreased sensitivity to different levels: insulin, glucagon, and catecholamine receptors. Then, the responses controlled by these three mediators are smoothed.